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STUDIES ON THE FEEDING VALUE OF ACETIC, PROPIONIC, AND LACTIC ACIDS WITH GROWING-FATTENING LAMBS [1]

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INTRODUCTION

One of the unique digestive processes occurring in the forestomach or rumen of cattle and sheep is the formation of volatile fatty acids from carbohydrates. Amino acids can also be metabolized to yield fatty acids by rumen micro-organisms (16). In the rumen, the microflora convert the cellulose portion of hays, meadow crops and silages and starch from grains, etc. (carbohydrates) chiefly into acetic, propionic and butyric acids plus traces of higher acids, such as valeric, caproic, iso-valeric and iso-butyric. These water soluble acids can then be absorbed into the blood stream via the walls of the rumen-reticulum and omasum and thence transported to the various tissues where the acids are metabolized to yield energy.

By contrast, mono-gastric animals, such as swine, break down starch to the simple sugar, glucose, which is absorbed and metabolized to yield energy. Thus, in the ruminant animal, the volatile fatty acids serve a function comparable to glucose in the non-ruminant animal. In addition, the volatile fatty acids produced in the rumen have special functions, such as the utilization of acetic acid in the synthesis of milk fat by the mammary gland (11) while propionic acid can be converted to glucose in the liver. McClymont (8) has theorized that the high heat increment of feeding in ruminants is the result of the metabolism of acetic acid formed in the rumen.

An indication of the amount of acids formed in the rumen is that an estimated 13 to 50 percent of the energy requirements of the ruminant animal is supplied by the metabolism of the absorbed volatile fatty

[1]A preliminary report of this work was presented at the meeting of the American Society of Animal Production, November, 1954, and an abstract appears in the Journal of Animal Science **13:** 976, 1954.

[2]The technical assistance of T. V. Hershberger and L. D. Kamstra in carrying out the analyses of meat and rumen samples is gratefully acknowledged.

acids. This figure may be even higher as it is difficult to evaluate. It has been estimated that the rumen-reticulum of the sheep contains 64 grams (2 oz.) of acids expressed as acetic acid (5). Presumably the remainder of the energy needs of cattle and sheep are derived from the metabolism of simple sugars, fats, and protein which by-pass digestion in the rumen and are subjected to enzymatic digestion in the region of the stomach and small intestine, much as in the simple-stomached animal.

These same fatty acids are known to occur in natural feeds, particularly corn and grass silage. For example, Barnett (2) states that a grass silage can contain as much as 7.18 percent of volatile fatty acids on a dry matter basis of which 51.4 percent was acetic, 8.8 percent propionic acid, 30 percent butyric acid, 5 percent valeric acid and 3.8 percent caproic acid. Levels of as high as 6 percent lactic acid have been reported for clover-grass silage on a dry matter basis, but a 3 percent lactic acid level in corn silage is frequently found.

A recent development has been the use of acetic or propionic acids in the prevention and treatment of ketosis, Schultz **et al.** (14). The utilization of these acids for energy, growth, etc., should be considered in the overall evaluation of their use as therapeutic agents in ketosis treatment.

Although it has been known for many years that the volatile fatty acids are produced in the rumen, only a limited amount of work on the feeding value of the acids has been done.

Since the ruminant animal utilizes large amounts of volatile fatty acids and the relative amounts of the acids produced varies with the type of carbohydrates fed, the possibility that feeding fatty acids might affect meat flavor was considered. If there are actual flavor differences between corn and grass fattened animals, possibly this could be due to the differences in the types of fatty acids being metabolized by the tissues.

In this report, the results of lamb feeding experiments using a fattening type ration to which acetic, propionic or lactic acid were added, carcass evaluations for the lambs, analysis of the meat for fatty acids, and flavor evaluation (organoleptic) of the meats are presented. The experiments were carried out at the Ohio Agricultural Experiment Station, Wooster, and at Ohio State University.

PROCEDURE

Experiment I

In the first experiment (1952-1953), acetic and propionic acids as their sodium salts, were fed both alone or in combination in an attempt to determine their effect on rate of gain, efficiency of feed utilization, carcass grade and meat quality. A low level of corn feeding was used since it was desirable to determine the effect of the acids when added to rations containing a high proportion of roughage.

Feeding Trial:

Twenty-four Columbia-Shropshire lambs from the Station flock were divided into four lots of 6 lambs each. The lambs averaged about 63 pounds at the beginning of the feeding trial. Each lot received a basal ration of 0.5 lb. of ground corn and 0.25 lb. of Cerelose[3]-urea mixture (mixed to supply 0.17 lb. of protein equivalent) per head per day and a full feed of a mixed clover-timothy hay. All lots were fed minerals, free choice, consisting of 3 parts steamed bone meal, 3 parts ground limestone and 1 part trace mineralized salt. In addition, Lot 2 received sodium acetate, Lot 3 received sodium propionate[4] and Lot 4 received a 50-50 mixture of sodium acetate and sodium propionate. Initially, the acid salts were fed at 20 grams per day, but the amount was gradually increased by 10 gram increments until the lambs were eating 80 grams per day. The average acid consumption per day per lamb for the entire feeding period was about 47 grams. The lambs were weighed weekly.

After 109 days on this feeding regimen, the lambs were slaughtered in the Ohio State University Meats Laboratory at which time detailed carcass data were obtained.

Biochemical Analysis:

Samples of rumen contents, blood, livers and meat were taken at slaughter for purposes of fatty acid and metabolic acid analysis. The samples were preserved by the techniques described below.

BLOOD: Arterial blood was defibrinated mechanically. Twenty-five ml. of blood was adjusted to pH 10 with 1.5 ml. of 4N NaOH, and the alkaline samples was lyophilized and stored at —15° C.

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[3]A product prepared from corn sugar manufactured by the Corn Products Refining Company, New York, N. Y.

[4]The sodium propionate used in these studies was kindly supplied by the I. E. du Pont de Nemours Company, Wilmington, Delaware, through the courtesy of Drs. M. F. Gibbons and I. Belasco.

LIVER: Forty-five grams of liver were homogenized with 30 ml. water and 10 ml. 4N NaOH in a Waring blendor. The homogenate was lyophilized and stored.

MEAT: One hundred grams of meat were homogenized with 250 ml. water and 2.5 ml. 4N NaOH in a Waring blendor. The homogenate was lyophilized and stored.

RUMEN JUICE: The rumen was ligated at both ends, removed from the animal, and the rumen contents were removed and strained through a double layer of cheesecloth. One hundred ml. of the liquid were adjusted to pH 10, lyophilized, and stored at —15° C.

The procedure of Bulen **et al.** (4) was used to determine acetic, propionic, butyric, pyruvic, lactic, fumaric, succinic, α-ketoglutaric, trans-aconitic, malic and citric acids in the preserved samples.

Moisture, fat and pH were determined on the meat and liver samples by conventional methods.

Flavor Studies:

For taste testing, the meat from one entire shoulder was boned, ground three times through a 1/8 inch plate, and mixed well. Flavor studies were conducted by six experienced testers and six inexperienced testers (13). The triangle technique was used on samples from loaves consisting of 3.5 pounds of raw meat blocked in rectangular molds of identical shape and roasted simultaneously to 180° F. internal temperature in a 325° F. rotary hearth oven. Since all testing was done in duplicate, the limited samples only permitted comparisons of Lot 1 with Lots 2 and 3.

Experiment II

The second feeding experiment was carried out during 1953-1954 in a manner similar to the first experiment. The basal ration was supplemented with a mixture of acetic and propionic acids, as before, and, in addition, one lot was given lactic acid. The fourth lot was given an additional portion of corn to compare the effect of energy from a crude source to that supplied in a pre-digested form, as the acids.

Twenty-four Wyoming white face feeder lambs, obtained through the Cleveland Producers Livestock Association, were allotted equally into four dietary groups. Each lamb received a basal ration of 0.75 lb. ground corn and good quality second-cutting alfalfa hay fed free choice. In addition, the lambs were given free choice minerals, consisting of 2 parts steamed bone meal, 2 parts ground limestone and 1 part trace mineralized salt. Based on calculations, this ration provided the minimum energy and protein as recommended for growing-fattening lambs by the National Research Council (12).

Lot 2 lambs received an additional supplement of 38.8 grams per head per day of a 50-50 mixture of sodium acetate and sodium propionate. Lot 3 lambs received 69.8 grams per head per day of a 60 percent sodium lactate[5] solution. Lot 4 lambs received an additional 0.13 lb. of corn per head per day. Since Lots 2 and 3 were receiving the acids as their sodium salts, the sodium intake was balanced by the addition of 31 grams of sodium bicarbonate per head per day to Lots 1 and 4. The lambs were weighed weekly.

In this experiment, the diets for Lots 2, 3, and 4 were designed so as to be isocaloric. This was not done in the previous experiment. Acetic, propionic and lactic acids were assumed to be utilized with 100 percent efficiency by the ruminant. Their caloric values (heats of combustion) are as follows: acetic acid, 3.62 Cal./gm., propionic acid, 4.96 Cal./gm., and lactic acid, 2.49 Cal./gm. (7). In a discussion of Kellner's work, Breirem (3) stated that the rumen has been said to be 50 percent efficient for the conversion of starch to usable forms of energy. The caloric value of corn used was 3.97 Cal./gm. (10) or at 50 percent efficiency, 1.98 Cal./gm.

During the second feeding trial, 48 hour urine collections were made from one lamb in each lot. Aliquots of these urine samples were analyzed for acetic, propionic and butyric acids by the silica gel column technique.

After 84 days on this feeding regimen, the lambs were slaughtered at the Ohio State University Meats Laboratory and carcass data were obtained.

RESULTS

Tables 1 and 2 summarize the growth, feeding and carcass data for Experiments I and II, respectively.

Growth and Feeding Results:

In Experiment I, the lambs in all three acid-fed lots had slightly higher rates of gain but the differences were not statistically significant. Similarly, in Experiment II, the supplemented lots showed trends toward faster rates of gain but again the differences were not significant.

In both experiments, the supplementation with the acid salts had a marked effect on feed efficiency. In Experiment I, the three supplemented lots required 16.5, 15.9 and 15.4 pounds of total feed per pound of gain as compared to 17.8 pounds of total feed per pound of gain for

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[5]The sodium lactate used in these studies was kindly supplied by Merck and Company, Rahway, New Jersey, through the courtesy of Dr. L. Michaud.

TABLE 1.—Feeding, Growth and Carcass Data for Lambs Supplemented with Acetic and Propionic Acids (Experiment I, 1952-1953)

	Lot 1	Lot 2	Lot 3	Lot 4
	Basal	Acetate	Propionate	Acetate and propionate
Number in lot	6	6	6	6
Average weight, Sept. 26, 1952	63.5	64.0	63.6	63.3
Average weight, Jan. 13, 1953	87.0	91.0	90.5	91.2
Average daily gain, 109 days	0.22	0.25	0.25	0.26
Average daily ration, lb.:				
Ground corn	0.5	0.5	0.5	0.5
Cerelose-urea supplement	0.315	0.315	0.315	0.315
Hay	3.05	3.22	3.03	3.05
Acetic acid		0.075		0.038
Propionic acid			0.079	0.040
Feed req. per pound gain, lb.:				
Ground corn	2.30	2.01	2.02	1.95
Cerelose-urea supplement	1.45	1.27	1.28	1.23
Hay	14.05	12.93	12.28	11.90
Acetic acid		0.31		0.15
Propionic acid			0.32	0.16
Carcass grade	4 Prime 2 Choice	5 Prime 1 Choice	5 Prime 1 Choice	6 Prime
Dressing percentage (Fall shorn)	54.0	55.7	55.6	54.6

the basal lambs. In the second experiment, the acid supplemented lot required 12.2 and 10.8 pounds of feed per pound of gain as compared to 12.9 pounds for the basal animals. This feed saving is even better illustrated by calculating the apparent feed replacement values for the acids in each experiment by the following formula:

$$\text{Apparent Feed Replacement Value} = \frac{\text{Total feed/lb. gain, basal lambs} - \text{Total feed/lb. gain, acid-fed lambs}}{\text{Pounds of acid used per lb. gain}}$$

Although this calculation is empirical, it estimates the relative feeding value of the acids fed. These data are shown in Tables 3 and 4. In Experiment I the acids fed had replacement values of from 5 to as high as 9, i. e., one pound of acid replaced or spared between 5 and 9 pounds of feed per unit of gain. The mixture of acetic and propionic acids fed in Experiment II did not have as high a replacement value as in the first experiment (3.52 vs. 9.27, res.). However, lactic acid had

TABLE 2.—Feeding, Growth and Carcass Data for Lambs Supplemented with Acetic and Propionic Acids, Lactic Acid or Additional Corn (Experiment II, 1953-1954)

	Lot 1	Lot 2	Lot 3	Lot 4
	Basal	Acetate and propionate	Lactate	Additional corn
Number in lot	7	7	6	6
Average weight, Nov. 11, 1953	73.4	72.8	73.5	75.6
Average weight, Feb. 2, 1954	98.9	99.6	103.8	104.1
Average daily gain, 84 days	0.30	0.32	0.36	0.34
Average daily ration, lb.:				
Ground corn	0.75	0.75	0.75	0.89
Hay	3.09	3.08	3.07	3.07
Acetic acid		0.031		
Propionic acid		0.033		
Lactic acid			0.074	
Sodium bicarbonate	0.067			0.069
Feed req. per pound gain, lb.:				
Ground corn	2.48	2.35	2.08	2.62
Hay	10.22	9.64	8.49	9.06
Acetic acid		0.097		
Propionic acid		0.102		
Lactic acid			0.205	
Sodium bicarbonate	0.22			0.20
Carcass grade	3 Choice+ 3 Choice 1 Good	3 Choice+ 2 Choice 1 Choice— 1 Good	4 Choice+ 1 Choice— 1 Good	
Dressing percentage	51.5	51.8	53.6	51.8

an apparent feed replacement value of 10.24 which is even higher than that for acetic and propionic acids as found in Experiment I. Much of the feed replaced (or saved) was hay, which, because of refusals of stemmy material and waste problems, is difficult to measure accurately even though the uneaten portion was weighed back. However, the saving was also reflected in the more accurately measured corn and supplement portions of the ration.

When the feed replacement values of the acids in Experiment II are calculated, using the isocaloric corn ration (Lot 4) as a reference ration, the data presented in Table 5 are obtained. These data suggest that the mixture of acetic and propionic acids was not superior to additional corn on an isocaloric basis but that lactic acid was still quite superior.

TABLE 3.—Efficiency of Utilization and Apparent Feed Replacement Values of Fatty Acids (Experiment I)*

Lot	Pounds feed/lb. gain				Total feed per pound of gain	Total feed replaced per pound of acid
	Hay	Corn	Supple-ment	Acids		
Basal	14.1	2.3	1.5		17.9	
Basal + acetate	12.9	2.0	1.3	0.310	16.5	5.48
Basal + propionate	12.3	2.0	1.3	0.322	15.9	7.14
Basal + acetate + propionate	11.9	2.0	1 2	0.302	15.4	9.27

*Apparent Feed Replacement Value = $\frac{\text{Total feed/lb. gain, basal lambs} - \text{Total feed/lb. gain, acid–fed lambs}}{\text{Pounds acid used per pound gain}}$

Since acetic and propionic acids are end products of carbohydrate digestion in the rumen it might be thought that their presence in the ration would inhibit hay consumption. The data in Table 1 show that this is not the case. For example, the hay consumption of the Lot 2 lambs was more than for the basal lot.

TABLE 4.—Efficiency of Utilization and Apparent Feed Replacement Values (Experiment II)*

Lot	Pounds feed/lb. gain			Total feed per pound of gain	Total feed replaced per pound of acid*
	Hay	Corn	Acid		
Basal	10.2	2.5		12.7	
Basal + acetate + propionate	9.6	2.4	0.199	12.2	3.52
Basal + lactate	8.5	2.1	0.205	10 8	10.24
Basal + additional corn	9.1	2.6		11.7	

*Apparent Feed Replacement Value = $\frac{\text{Total feed/lb. gain, basal lambs} - \text{Total feed/lb. gain, acid–fed lambs}}{\text{Pounds acid used per pound gain}}$

TABLE 5.—Apparent Feed Replacement Values of Acids Using the Isocoloric Corn Ration (Lot 4) Experiment II, as a Reference*

Lot	Pounds feed/lb. gain			Total feed replaced per pound of acid
	Hay	Corn	Acid	
Basal + acetate + propionate	9.6	2.4	0.199	—1.51
Basal + lactate	8.5	2.1	0.205	+5.37
Basal + additional corn	9.1	2.6		

*Apparent Feed Replacement Value = (Total feed/lb. gain, basal lambs — Total feed/lb. gain, acid—fed lambs) / Pounds acid used per pound gain

Carcass Data:

In the first experiment (Table 1), the lambs from the basal or control lot were surpassed in dressing percentage and in carcass grade by the lots that received sodium acetate, sodium propionate, or a combination of the two acid salts. However, the differences were small and not significant. Figures 1 and 2 show carcasses representing all four lots in Experiment I. These figures illustrate the similarity of carcasses in all lots.

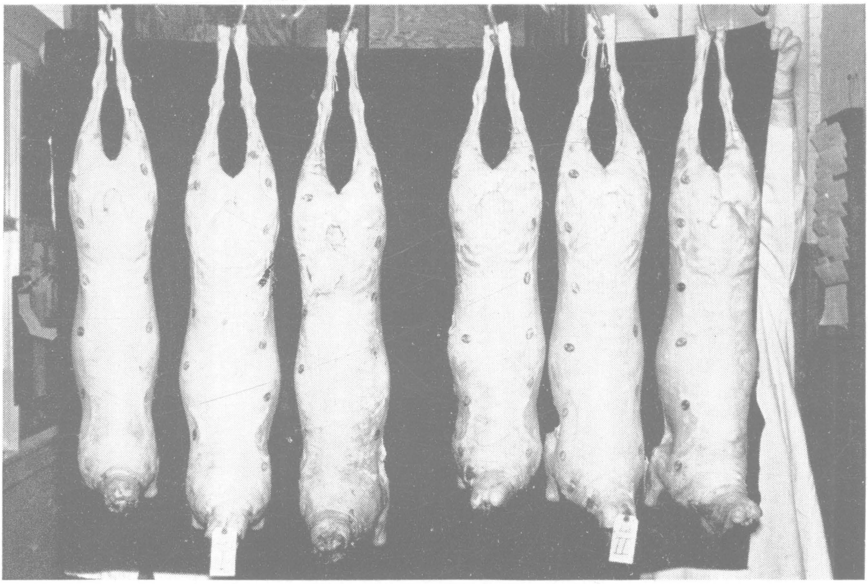

Fig. 1.—Lamb carcasses from Lots 1 and 2 of Experiment I

The lambs in Experiment II (Table 2) also showed small but insignificant differences in dressing percentage and carcass grade. The slightly greater dressing percentage of Lot 3 may be partially due to the fact that they were not held as long a time in the holding pen prior to slaughter as were Lots 1 and 2.

In general, the lambs from both experiments (1) were in excellent condition for market, (2) yielded well in weight, and (3) were acceptable in grade.

Analysis of the Tissues:

The rumen juice, liver, blood and meat of each of the lambs in Experiment I were analyzed for acetic, propionic and butyric acids and the values from all six lambs in a given lot were averaged. These averages as well as the standard deviations are given in Table 6. Figure 3 graphically illustrates the amounts of these acids in the tissues.

There were no marked differences in a given acid content of a given tissue due to treatment (ration supplement). The concentration of acetic acid in the tissues of the control lambs tended to be lower than that in the treated lots. No trend of difference appeared in the concentration of the other two acids. However, the large variation

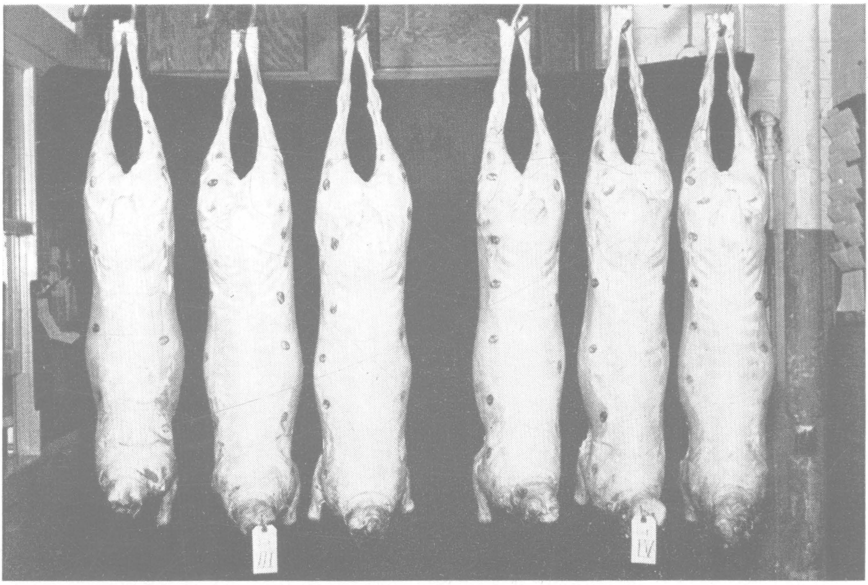

Fig. 2.—Lamb carcasses from Lots 3 and 4 of Experiment I

TABLE 6.—The Effect of Rations Containing Sodium Acetate and Sodium Propionate on the Distribution of Volatile Organic Acids in the Tissues of Lambs

Tissue	Butyric acid	Propionic acid	Acetic acid
	Milliequivalents of acid per ten grams of tissue—dry matter		
RUMEN JUICE			
Lot 1	3.12 ± .41	2.13 ± .79	10.86 ± 2.54
Lot 2	2.77 ± .73	3.38 ± 1 26	16.12 ± 5.28
Lot 3	3.18 ± 1 03	2.59 ± .62	12.97 ± 1.83
Lot 4	3 18 ± .35	3.54 ± .45	16.10 ± 1.90
LIVER			
Lot 1	.061 ± .017	.046 ± 016	.294 ± .144
Lot 2	.072 ± .050	.039 ± .026	.348 ± .068
Lot 3	.134 ± .132	.121 ± .056	.282 ± .166
Lot 4	.065 ± .046	.073 ± .051	.320 ± .168
BLOOD			
Lot 1	.052 ± .019	.060 ± .024	.129 ± .171
Lot 2	.028 ± .014	.034 ± .019	.260 ± .060
Lot 3	.026 ± .018	.064 ± .027	.288 ± .172
Lot 4	.053 ± .026	.066 ± .052	.222 ± .062
MUSCLE			
Lot 1	.027 ± .038	.014 ± .006	.057 ± .013
Lot 2	.020 ± .008	.018 ± .009	.850 ± .051
Lot 3	.037 ± .042	.025 ± 015	.087 ± .050

Lot 1—Basal.
Lot 2—Acetate treatment.
Lot 3—Propionate treatment.
Lot 4—Acetate and propionate treatment.

between animals within a lot (as indicated by the large standard deviations) indicates that these differences between treatment are not significant.

Table 7 shows the concentration of the three fatty acids in the rumen juice given as total acids and in mole percent of a given acid. The rumens from Lots 1 and 3 appeared to contain less total acids than those from Lots 2 and 4. Also, there were small differences in the concentration of the acids given as mole percent. However, since the fatty acid content of rumen liquor is subject to many changes, both in total acids and proportions of individual acids, the differences noted above are probably not significant. The proportions of the three acids in any case were not too far removed from what is considered to be normal, i. e., 15:20:65 mole percent ratios of butyric:propionic:acetic acids.

Figure 4 graphically presents the concentrations of metabolic acids in the livers, blood, and meat from the lambs in Experiment I. Most of the differences noted between tissues from different lots of lambs were small and of no significance. It did appear that the presence of acetic acid in the supplements (Lots 2 and 4) lowered the lactic acid content of the livers. This suggests that acetic acid may have an effect on

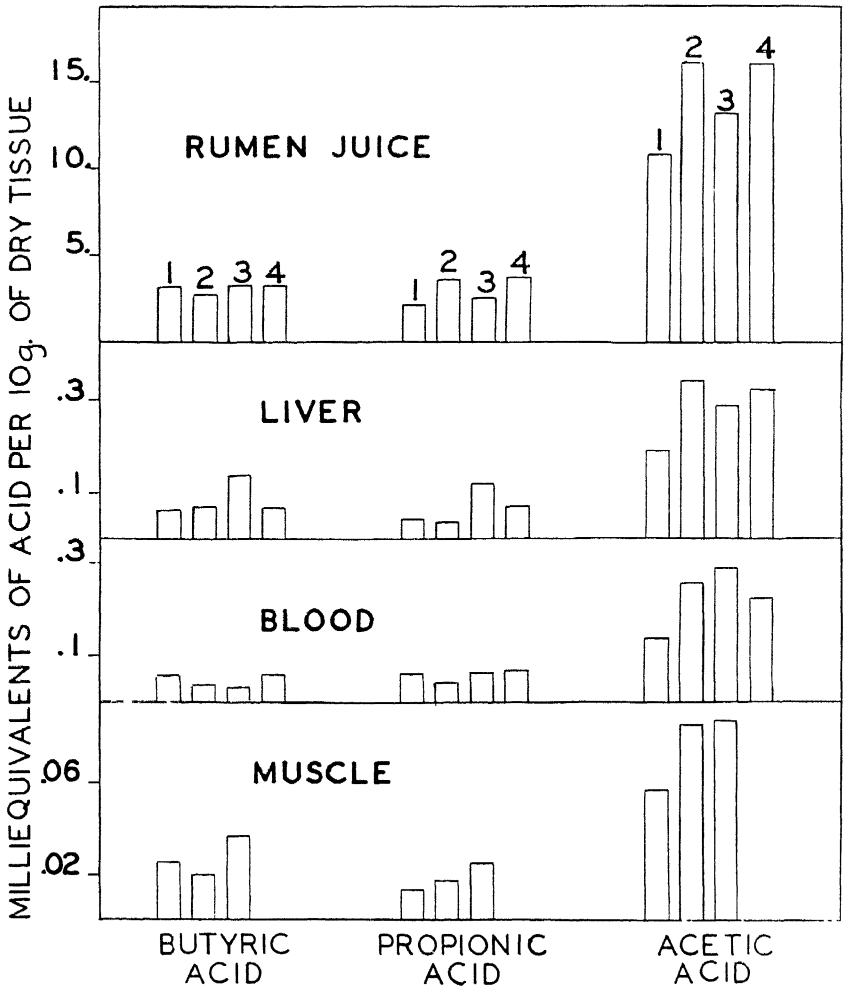

Fig. 3.—The concentration of butyric, propionic and acetic in rumen juice, liver, blood and muscle tissue samples from the Experiment I lambs. Numbers 1, 2, 3 and 4 refer to the different lots of lambs.

TABLE 7.—Short Chain Fatty Acids in Lamb Rumens—Experiment I

Lot	Number of lambs	Mg. acid per gram lyophilized rumen juice			Grams* acid in entire rumen	Concentration of acids in mole, percent		
		Butyric	Propionic	Acetic		Butyric	Propionic	Acetic
1	6	27.4	15.8	65.2	4.24	19.8	12.9	67.3
2	5	26.6	29.1	96.0	5.18	13.2	17.0	69.8
3	5	28.0	19.2	77.9	4.17	16.9	13.8	69.3
4	6	28.0	26.3	96.9	5.74	14.0	15.5	70.5

*Total acids per entire rumen—data taken from three animals in each lot.

lactic acid production or utilization. Also, the concentration of alpha-ketoglutaric acid was higher in the livers of acid supplemented lambs. The significance of this observation is unknown.

The data from pH, fat and moisture determinations of the shoulders of lambs in Lots 1, 2 and 3 are presented in Table 8. The pH of the meat tended to be higher in the acid supplemented lots. This may be correlated with the slightly higher concentrations of acetic and lactic acids in the muscle of acid fed lambs. The meat from the acetate fed lambs had a higher percentage fat composition than the controls and the propionate fed lambs were still higher. As a result of this higher fat content, the moisture content was correspondingly lower.

Flavor Comparisons:

Flavor comparisons were made on meat for lambs in the first three lots. There was not sufficient sample to make a comparison of the meat from Lot 4 with meat from the other lots. The results of these taste panels have been described in detail by Royal (3). Both experienced and inexperienced tasters were used. With the inexperienced tasters, the number of flavor differences detected was not large enough to be differentiated from chance alone. However, the experienced

TABLE 8.—The Effect of Acetate and Propionate Feeding on the pH, Moisture and Fat Content of Ground Lamb Shoulders (Experiment I)

Treatment	Animals	pH	Percent moisture	Percent fat
Lor 1—Basal	6	5.99	47.8±4.6	38.6±3.4
Lot 2—Acetate	6	6.22	44.6±4.7	40.0±5.8
Lot 3—Propionate	6	6.10	42.9±2.5	42.1±5.1

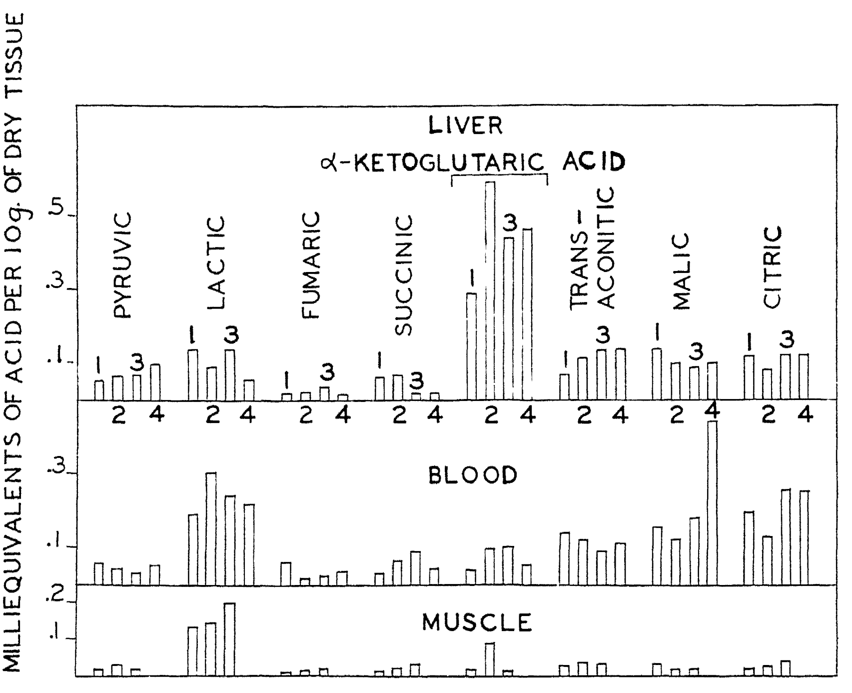

Fig. 4.—The concentration of metabolic acids in liver, blood and muscle tissues from the Experiment I lambs. The numbers 1, 2, 3 and 4 refer to the different lots of lambs in the experiment.

tasters detected enough differences in flavor that these differences could not be assigned to chance alone. In other words, the panel could discern a difference in the flavor of the acetate or propionate fed lambs as compared to the control lambs. These findings in flavor differences have no bearing on the preference evaluation of the meat and do not incriminate or compliment any of the groups. They merely state that a difference in flavor was observed.

Fatty Acids in the Urine:

Table 9 gives the quantity of short chain fatty acids in the urine of the lambs from Experiment II. The most significant observation was that the concentration of butyric acid in the urine was considerably higher than that of acetic and propionic. Also, the butyric acid content in the urine of the acid supplemented lambs was about twice as high as that in the control lambs. Actually, the total quantity of acids in the urine is of little consequence when one realizes that a lamb on this

TABLE 9.—Fatty Acids in Urine of Sheep Fed Fatty Acids or Lactic Acid (Experiment II)

Ration	Acids*		
	Acetic	Propionic	Butyric
Lot 1—Basal	0.08	0.03	0.32
Lot 2—Basal + acetate + propionate	0.12	0.04	0.64
Lot 3—Basal + lactate	0.10	0.05	0.63
Lot 4—Basal + additional corn	0.08	0.07	0.20

*Grams per 100 ml. urine.

ration excretes about 400 ml. of urine over a 24-hour period. Thus these lambs would be excreting from 1 to 4 grams of acid per day compared with an intake of 50 grams of supplemental acids plus those synthesized in the rumen.

DISCUSSION

It is apparent from these results that the volatile fatty acids, acetic and propionic acids, fed as sodium salts and sodium lactate are used as energy sources by growing-fattening lambs. Furthermore, pound for pound, the fatty acids tested were much more efficiently used than the remainder of the ration. Lactic acid appeared to be more efficient than additional energy supplied as corn.

The efficient use of volatile fatty acids and lactic acid in the ration of ruminants has been reported previously. Zelter (19) noticed that dairy cows produced more milk when fed silage and attributed the increase in production to ingestion of acetic and butyric acids in the silage ration. In another experiment, Zelter (19) found that the addition of either calcium acetate plus calcium butyrate or silage to the ration gave milk and fat yields above expectation. When individual acids were fed, acetic acid gave an immediate effect. Butyric acid alone had no effect but butyric plus pyruvic had a small effect. When acetic was added to these two acids, the effect was equal to that of acetic alone. Tyznik (17) and Van Soest **et al.** (18) have shown that on certain types of rations a decrease in the amount of acetic acid in the rumen of cows occurs. This decrease in acetic acid is associated with a depression of milk fat. Feeding of sodium acetate produced a recovery to normal fat levels in the milk. Miller and Allen (9), on the other hand, found that feeding of one pound of sodium acetate for ten day periods to normal cows on normal diets had no significant effect on milk and fat production, fat test, blood glucose, or blood ketones.

A partial explanation of these observations is the well-known fact that acetic acid is a major precursor of milk fat in the mammary tissue of ruminants (11).

It is not surprising that these acids should have a high feed replacement value. Since they are end products of the natural digestive processes occurring in the rumen, they would not be subjected to the digestive losses and inefficient utilization typical of natural feedstuffs in ruminants. In other words, these acids (acetic and propionic) would be absorbed directly and be of use to the host animal itself. Lactic acid may or may not be subjected to further metabolic change before being used by the host. Hershberger **et al.** (6) found that lactic acid is converted to acetic and propionic acids by rumen micro-organisms **in vitro.**

In certain areas of Europe mineral acids are being used in the making of silage. It would seem advantageous if one or more volatile fatty acids studied herein could be used in place of phosphoric acids, since the former organic acids would contribute to the energy content of the silage. Another possible application of these findings might be in the consideration of ammonium salts or amides of these acids as non-protein nitrogen carriers in that it would carry an energy source as well as nitrogen.

The data on flavor and fatty acids content of the meat from these lambs brings up an interesting point. Since all carbohydrates yield fatty acids upon their digestion in the rumen, it would be doubtful if the carbohydrates from corn, small grains or hay would effect meat flavor by virtue of the fatty acids produced. In this study varying amounts of the pure fatty acids were fed without influencing meat flavor to any great extent. Thus it would appear that the importance of feeding in quality of meat animals is to provide sufficient energy for growth and proper conditioning. For example, Simone, Carroll, Hinreiner and Clegg (15) have found that animals fed to certain grades (condition) have comparable meat quality scores irrespective of type of carbohydrate fed. This conclusion seems fundamentally sound because of the previously mentioned mechanism of carbohydrate digestion and the fact that utilization of the major rumen acids for energy by animal tissues results in meat of comparable flavor.

SUMMARY

Forty-eight lambs were used in a feeding trial to determine the efficacy of salts of acetic, propionic and lactic acids as energy sources in a growing-fattening type ration.

The addition of acetic, propionic or lactic acids to a corn-cerelose-urea-hay or a corn-hay ration produced some but not significant increases in the average daily gain of lambs fed to about 100 pounds. However, a marked feed saving was elicited by these acids. When apparent feed replacement values were calculated, one pound of acid was shown to replace from 3 to 10 pounds of feed per unit of gain.

The carcasses of the acid supplemented lambs were very similar to those of the non-acid fed control animals. All lots graded well.

Tissue analyses demonstrated no greatly significant differences in the acetic, propionic, butyric, and metabolic acid contents of the rumen juice, liver, blood and meat of the lambs. Some slight differences did occur. The meat from the acid-fed lambs tended to be higher in pH and in fat and lower in moisture.

An experienced taste panel could detect a flavor difference between the meat of acid fed animals and of control animals. The difference, however, did not incriminate or compliment either lot.

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